Specific PVMaT R&D in CdTe Product Manufacturing

S. Henson, K. Smigielski, J. Hanak, F. Borgeson, P. Meyers, A. McMaster
First Solar, LLC
28101 Cedar Park Blvd., Perrysburg, OH 43551

ABSTRACT

First Solar, with the support from the PVMaT program, has completed an effort centered on three areas of work. The first area: "Manufacturing Line Improvements" involved the design, construction and implementation of a high-speed laser scribing system capable of matching the throughput of a thin-film, solar cell manufacturing line of 20 MW/year. Significant increases in the reliability of equipment and decreases in the down time and capital costs were realized. Additionally, an improved potting and lamination system was developed. The second area of effort: "Product Readiness" focused on product safety and marketplace acceptance. The product was submitted and obtained UL 1703 and IEC 61646 certification. The third work area: "Environmental, Safety and Health Programs" resulted in the development of safety, training and employee health monitoring programs along with the development of plans to obtain ISO 14000 (or equivalent) certification.

1.0 Manufacturing Line Improvements

Laser scribing of solar panels using thin-film solar cells is used for cell interconnections [1]. The objective of this project was to develop a system for scribing solar panels, measuring 120 cm x 60 cm, with a throughput of one per minute, at a reduced capital cost, improved reliability, improved scribe control and requiring the use of a single laser beam per each of three types of scribes.

The system developed is capable of achieving a 60-cm-long scribe line, having a minimum theoretical spot size of 70 microns. Scribe-to-scribe location is easily controlled. The scribing can reach speeds in excess of 3400 mm/sec, through the use of pulsed lasers having a high rep-rate. A key benefit of this system is the ability to use a correction factor in the software, which allows cell mapping and correcting the focus for uneven surfaces. In order to achieve speeds above 2000 mm/sec, scribing through the glass side of the solar panel, reported earlier [2], was pursued.

Green-light (532 nm) lasers are typically used for solar cell scribing in order to match the wavelength to the optical absorption of the material. In this project it was determined to use near-infrared (IR) lasers after developing the understanding that the CdTe absorption increases greatly with temperature for near-infrared (IR) wavelengths.

Considering the structure of the solar panels, from the sunny side, it consists of a soda-lime glass plate superstrate, coated with layers of TCO/CdS/CdTe/metal, encapsulated by a second plate of glass. The TCO signifies transparent conductive oxide. In the scribing sequence used at First Solar, each scribe removes a smaller amount of material compared to its predecessor, thus the top-most layers can be removed at low energies without damaging the inner layers. Scribe-1 removes all the layers on the glass; scribe-2 removes the CdS and CdTe, without ablating the TCO. Scribe-3 removes the metal layer, applied after scribe-2; the metal is removed chiefly by the high-pressure CdTe vapor formed at its interface by the beam reflected by the metal.

Improvements with the improved scribing system include: (1) Reduced capital cost - the cost of high-speed improved laser system is about 65% less than that of a conventional system, with four nozzles; (2) reduced and lower-cost maintenance, which reduces down-time by a factor of ten; (3) greatly enhanced location accuracy of subsequent scribes through the use of fiducials, coupled with automated correction for panel growth/ shrinkage caused by temperature variations as well as panel rotation; (4) substantially reduced kerf widths and scribe spacing, whereby the active area of the panel is increased; (5) IR lasers deliver about twice the power of frequency-doubled green lasers and have life expectancy of up to 10,000 hours, 14 times greater than green lasers, and lower cost; and (6) increased production throughput by a factor of four.

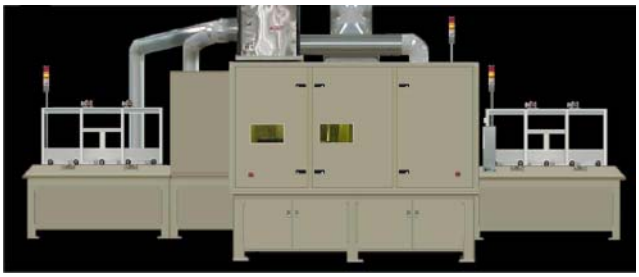

Figure 1. Fully automated Laser Scribing System

A high through put lamination process was developed. Industry consultants including [3] Automation and Robotic Research Institute (ARRI) and [4]Product Search were engaged in the development of a potting and lamination process capable of producing 60 modules per hour. Module performance data is obtained using an automated inline simulator and wet hi-pot system.

Research was conducted using liquid polyester resin, rubber EPDM, and Trueseal corporations hot melt butyl compound, in addition to or as a replacement for the current Ethyl Vinyl Acetate (EVA) encapsulant material. Research was conducted on replacement materials for the current tempered back cover glass and several potential materials were identified for the next generation product. Tom McMahon at NREL has assisted in this work through the development of several metal oxide barrier films. This effort will be continued in order to develop a lower cost, higher moisture barrier back cover layer for the CdTe module.

2. Product Readiness

R&D activities that were conducted to facilitate the UL and IEC certification include: (a) heat strengthening of glass to avoid breakage; (b) elimination of failures in the cord plate junction through the use RTV silicone potting material (c) relocation of the hole in the cover glass from 10 cm to 25 cm off the edge of the glass, thereby lowering the tensile stresses in the laminated module an average of 500 psi; and (d) screening of alternative encapsulants to EVA to improve electrical insulation during damp-heat testing.

In October 2002, nine standard production modules were submitted for testing to the Photovoltaic Testing Laboratory (PTL) at the Arizona State University, in accordance with the IEC standards. First Solar modules have completed the certification testing in accordance with IEC 61646 and have obtained international certification. Module power degradation was less than the 5% allowable and all performance requirements were met.

At the start of Phase III First Solar PV modules received "recognition" from the Underwriter Laboratories, which allowed the modules to be used on listed mounting systems.

During April 2001, and September 2002 modules were resubmitted to the Arizona Testing Laboratory with a c-channel and d-channel mounting system respectively. HF-10 and static load testing were successful and First Solar received authorization to use the UL Listed mark on its FS-50c and FS-50z and FS50d modules. These are complete modules with mounting attachments secured to the back side. The c, d, and z designations indicate the style of mounting with the c denoting aluminum c-channel rails, the d denoting aluminum d-channel and the z denoting aluminum z-bar rails.

A package was submitted to the California Energy Commission to qualify for the CEC buy-down program, which was approved in August 2001. First Solar was officially listed as an approved supplier on 8 Aug. 2001.

3.0 Environmental, Health and Safety Programs

EH&S capabilities were significantly advanced through implementation of detailed and comprehensive programs in each area - Environmental, Health and Safety, and a detailed plan was developed to obtain ISO 14000 certification. Over thirty specific tasks were completed during this subcontract period Among these tasks were: development and implementation of a personal protective equipment program, means of Egress plan, first aid/bloodborn pathogens training, electrical lockout/tagout training, light/noise/ ventilation evaluations, generation of reports to municipal and state agencies; equipment safety inspections; environmental sampling of R&D and production equipment and facilities for hazardous substances; installation and monitoring of EHS equipment; and periodic evaluation of employees for baseline cadmium. First Solar maintains a safe and healthy work place as well as an environmentally friendly manufacturing process and product. First Solar is continuing on plan to obtain ISO 14000 (or equivalent) certification.

4. Summary

First Solar has begun pilot manufacturing of high quality low cost thin-film CdTe modules. Through the assistance of this subcontract and NREL, First Solar has developed improved laser scribing systems and lamination equipment capable of producing greater than 60 modules/hr. The current module production has passed all testing requirements for UL 1703 and IEC 61646 and is certified by the Photovoltaic Testing Laboratory at Arizona State University and Underwriters laboratory. During the past thee years First Solar, LLC has constructed a factory for the production of PV modules. The most important goal has been to create a safe and healthy work place as well as an environmentally friendly manufacturing process and product. EH&S capabilities have been significantly advanced through implementation of detailed and comprehensive programs in each area - Environmental, Health and Safety.

ACKNOWLEDGEMENTS

First Solar would like to recognize the technical support from the thin-film team at NREL, and the continued support from Rick Mitchell through the course of this project. This work is supported in part through the NREL PVMaT Subcontract No. ZAX-8-17647-06.

REFERENCES

[1] Joseph J. Hanak, "Laser Processing Technique for Fabricating Series-Connected Solar Cells into a Solar Battery," U.S. Patent 4,292,092, September 29, 1981.

[2] David Carlson et al., "Electrical Contacts for a Thin-Film Semiconductor Device," U.S. Patent 4,854,974, August 8, 1989.

[3] Automation and Robotics Research Institute 7300 Jack Newell Blvd. South, Fort Worth, Texas 76118-7115

[4] Product Search Scottsdale, Arizona